

Recent Results from D0

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Abstract.

We discuss recent (B physics) results from D0. The results presented here correspond to an integrated luminosity of $\approx 115 \text{ pb}^{-1}$ of data collected at the Tevatron, between April 2002 and June 2003, at a center of mass energy of ($p\bar{p}$ collisions) of 1.96 TeV.

INTRODUCTION

The B physics program at D0, is designed to be complementary to the program at the B -factories at SLAC and KEK and includes studies of B_s oscillations, quarkonia (J/ψ , χ_c , Υ), searches for rare decays such as $B_s \rightarrow \mu^+\mu^-$, B spectroscopy, *e.g.*, B_{sJ}^* , lifetimes of the different B hadrons, search for the lifetime difference in the B_s CP eigenstates, study of beauty baryons, B_c , b production cross-section, etc.

One of the more important topics in B physics is the search for B_s \bar{B}_s mixing. Global fits to the unitarity triangle, assuming that the Standard Model is correct, indicate that the 95% CL interval for the mixing parameter ΔM_s is $(14.2\text{--}28.1)\text{ps}^{-1}$ [1]. The current limit¹ is $\Delta M_s > 14.9\text{ps}^{-1}$ at the 95% CL [1]. A measured value of ΔM_s much larger than the upper limits given here could pose a problem for the Standard Model.

acceptance. Tracks with pseudo-rapidity (η) as large as $2.5\text{--}3.0$ ($\theta \approx 10^\circ$) and transverse momentum (p_T) as low as 180 MeV/c are reconstructed.

The muon system can identify muons within $|\eta| < 2.0$. The minimum p_T of the reconstructed muons varies as a function of η . In most of the results presented here, we required muons to have $p_T > 2 \text{ GeV}/c$.

Low p_T electron identification is currently limited to $p_T > 2 \text{ GeV}/c$ and $|\eta| < 1.1$; however, we are working to improve both the momentum and η coverage.

A Silicon based (hardware) trigger is being commissioned which will allow us to trigger on long-lived particles, such as the daughters of charm and beauty hadrons. We expect to start including this trigger in the online system after the current Tevatron shutdown ends in Mid-November. We are currently making impact parameter cuts at Level 3 (software trigger). The hardware trigger will allow us to make these cuts at an earlier stage.

D0 DETECTOR

For the current run of the Tevatron (Run II), the D0 detector went through a major upgrade. The inner tracking system was completely revamped. The detector now includes a Silicon tracker, surrounded by Scintillating Fiber tracker, both of which are enclosed in a 2 Tesla solenoidal magnetic field. Pre-shower counters are located before the calorimeter to aid in electron and photon identification. The muon system has been improved, *e.g.* more shielding to reduce beam background was added.

The D0 detector has excellent tracking and lepton

DATA SAMPLE

The results presented here are based on data collected between April 2002 and June 2003. The dataset correspond to an integrated luminosity of about 115 pb^{-1} . We collected data with a dimuon as well as a single muon trigger. To reduce the data rate, a luminosity dependent prescale was applied to the single muon trigger (the prescale was 1 for instantaneous $\mathcal{L} < 20 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$). In both these triggers, the requirement that muons have hits in all layers of the muon system implies that they have total momentum $\geq 3 \text{ GeV}$.

¹ The limit is derived by combining limits from 13 different measurements

RESULTS

B_s oscillations is one of three processes where the flavour of the initial state changes by two units, the others being $K\bar{K}$ and $B_d^0\bar{B}_d^0$ mixing. Studies of $K\bar{K}$ mixing yielded results on indirect and direct CP violation, whereas the (unexpected) large value of $B_d^0\bar{B}_d^0$ mixing implied that the top quark was much heavier than expectations. If our current understanding of the Standard Model and the CKM matrix are correct, then B_s oscillations should be in the allowed region, and any deviation could be a sign of new physics. If the mixing parameter, ΔM_s is very large then the difference in the widths of the CP eigenstates of the B_s may be detectable.

The significance of a B mixing measurement can be expressed as,

$$\text{Sig.} = \sqrt{\frac{N\epsilon D^2}{2}} \exp^{-(\Delta M_s \times \sigma_t)^2/2} \sqrt{\frac{S}{S+B}} \quad (1)$$

where N is the number of reconstructed B_s events, ϵD^2 is a measure of how well we know the flavour of the B_s at production, σ_t is the proper time resolution, and $S/(S+B)$ expresses the cleanliness of the signal.

To study B_s oscillations we therefore need three ingredients, (a) final state reconstruction, (b) ability to measure B decay lengths, and (c) flavour tagging of the B both at production and decay².

Final State Reconstruction

We can reconstruct B_s in both the hadronic and semi-leptonic final states. The advantage of the former is that since it is a fully reconstructed decay, the proper time resolution is much better, whereas the branching fraction for the latter is much larger ($\approx 10\%$ vs. 0.5%).

In Fig. 1 we show the $B_s \rightarrow D_s \mu X$ signal for $\int \mathcal{L} \approx 6.2 \text{ pb}^{-1}$. The blue shaded histogram represents the wrong sign combinations. By comparison, we expect to see about $1.0 B_s \rightarrow D_s \pi$ events/ pb^{-1} .

In Figure 2, we present the inclusive $B \rightarrow D^{*-} \mu X$ signal for $\int \mathcal{L} \approx 6.2 \text{ pb}^{-1}$. The blue line represents the wrong sign combinations. We can use this mode to study B_d^0 mixing and for measuring inclusive B lifetime.

We will also reconstruct hadronic B_s decays, *e.g.*, $B_s \rightarrow D_s \pi$, as well as semi-electronic final states. Details about B hadron reconstruction at D0 can be found in E. Von Toerne's contribution to these proceedings.

² The latest results can be found at <http://www-d0.fnal.gov/Run2Physics/ckm/>

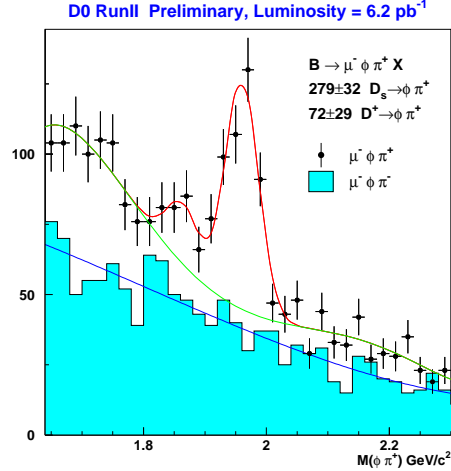


FIGURE 1. B_s semi-leptonic yield

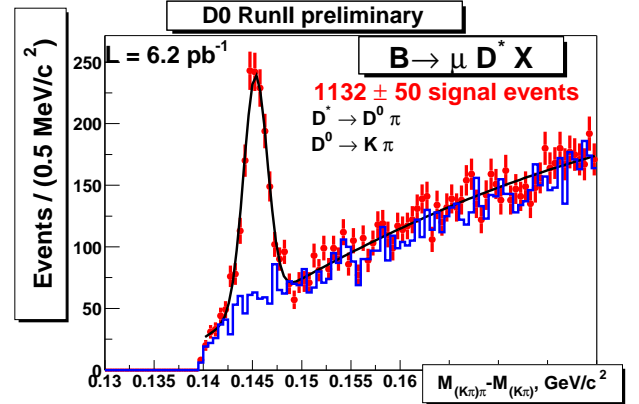


FIGURE 2. $B \rightarrow D^{*-} \mu X$

Lifetime Measurement

In Fig. 3, we present a measurement of the inclusive B lifetime using $B \rightarrow D^0 \mu X$ decays.

The background shape is obtained from the D^0 mass sidebands. Both sidebands and the signal regions are fitted with a combination of a Gaussian function to represent zero-lifetime background and exponentials (convoluted with Gaussian resolutions functions) to represent non-zero lifetime (the convolution is to take account of the smearing).

From the fit, we measure the inclusive B lifetime to be $438 \pm 25(\text{stat.}) \mu\text{m}$, which agrees with the world average, $472 \pm 2 \mu\text{m}$ [2]. We have also measured lifetimes for other B hadrons, and details can be found in Daria

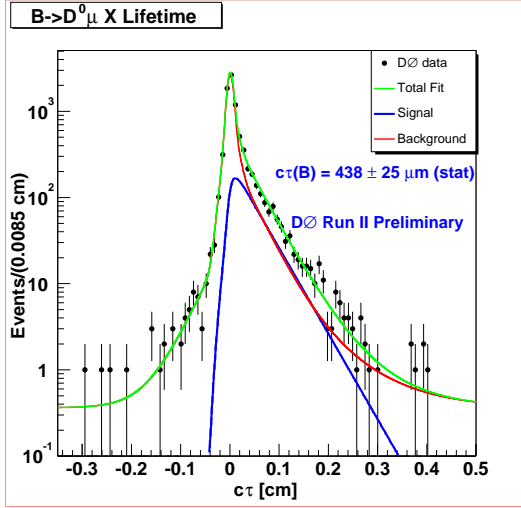


FIGURE 3. Lifetime for $B \rightarrow D^0 \mu X$

Zieminska's contribution to these proceedings.

Flavour Tagging

To be able to do a mixing measurement, one needs to know the flavour of the B hadron at the time of production and decay. By using flavour-specific decays, one can easily tag the flavour at the time of decay. Tagging the B flavour at production is more work. At D0, we plan to use the following techniques,

- **Soft Lepton Tagging:** The sign of the lepton produced in the semi-leptonic decay of the other B in the event is used to tag the flavour of the other B . We then make the assumption that the flavour of the decay B is opposite to that of the tag B . There will be some contamination due to the fact that the other B can mix, or that we pick up the tag lepton from a charm semi-leptonic decay. This method has low efficiency, but very high tagging power. We also plan to use electrons.
- **Jet Charge Tagging:** We take all tracks opposite to the decay B and form a track jet. The assumption is that these tracks are produced in the fragmentation of the other b -quark, as well as in the decay of the other B hadron. This method has high efficiency, but has poorer tagging power.
- **Same Side Tagging:** In this technique, we identify tracks produced in the fragmentation of the b -quark which gives rise to the decay B . In addition, the decay B can come from a resonance, *e.g.*, $B^{*+} \rightarrow B^0 \pi^+$, and one can use such pions to identify the flavour of the decay B at the time of production.

TABLE 1. Summary of flavour tagging results

	ϵ	Dilution(D)	ϵD^2
Soft Muon	5%	57%	$1.6 \pm 1.1\%$
Jet Charge	47%	27%	$3.3 \pm 1.7\%$
Same Side	79%	26%	$5.5 \pm 2.0\%$

This method has high efficiency, but has poorer tagging power

We benchmarked these techniques using a sample of $B^+ \rightarrow J/\psi K^+$ decays. Since the B^+ does not oscillate, it provides for a good testing ground.

In Figure 4, we show the B^+ peak for all events, events with a (jet-charge) tag, and events with the correct tag. We use the fits to these peaks to determine the efficiency (ϵ) and tagging power (Dilution) of the various techniques. $\epsilon = (N_R + N_W)/N_{all}$, and Dilution = $(N_R - N_W)/(N_R + N_W)$, where N_{all} , N_R and N_W are the number of all events, correctly tagged and wrongly tagged events, respectively.

The results for the various techniques are summarized in Table 1. We are in the process of checking these results on a sample of B_s and B^0 events.

B_s mixing

We expect to observe the following four classes of events,

- $B_s \rightarrow D_s \mu X$ collected with the single muon trigger. The flavour at production will be tagged using all three techniques discussed above.
- $B_s \rightarrow D_s \pi$ collected with the single muon trigger. In this case, we can use the trigger muon as the flavour tag. The tagging power will be very high in this case.
- $B_s \rightarrow D_s \mu X$ collected with the dimuon trigger. The flavour at production will be tagged using the second muon in the event.
- $B_s \rightarrow D_s e X$ collected with the single muon trigger. The flavour at production will be tagged using the trigger muon.

The semi-leptonic events have poorer proper time resolution compared to the hadronic mode, but much larger statistics. We are in the process of improving our estimate of the proper time resolution for both hadronic and semi-leptonic events. In addition, we can combine all modes to get a better measurement or a better limit.

If, we assume a resolution of ≈ 150 fs, we project that using the first class of events (with $\int \mathcal{L} \approx 500 \text{ pb}^{-1}$), we can make a 3σ measurement if $\Delta M_s \approx 12 \text{ ps}^{-1}$ or

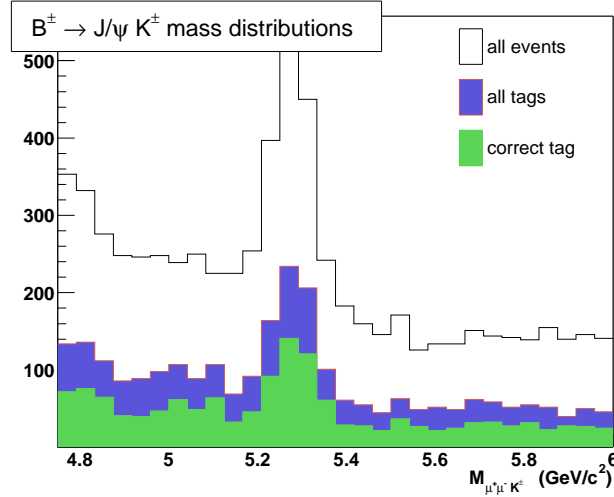


FIGURE 4. Fits for Jet Charge tagging results

a 1.5σ measurement if $\Delta M_s \approx 15 \text{ ps}^{-1}$. The third and fourth class of events have a very similar reach in ΔM_s .

For hadronic events (with the same luminosity), if the resolution is $\approx 110 \text{ fs}$, the corresponding numbers are a 3σ measurement if $\Delta M_s \approx 12 \text{ ps}^{-1}$ or a 2.2σ measurement if $\Delta M_s \approx 15 \text{ ps}^{-1}$.

Quarkonia

At the Tevatron, J/ψ can be produced either promptly (direct as well as indirect), i.e., $p\bar{p} \rightarrow J/\psi$ (or $\chi_c \rightarrow J/\psi$) or as a product in B decays. Υ by contrast are only produced promptly. The study of quarkonia sheds light on the strong interaction, especially non-perturbative QCD³

In Run I (at the Tevatron), the production cross-section of direct J/ψ was about 50 times larger than the Color Singlet Model.

With the new dataset, we plan to update the results on J/ψ production cross-section as a function of p_T and η , as well as study polarization effects. In addition, we are working to measure the absolute cross-section and polarization of the Υ states.

CONCLUSIONS

The D0 detector has started to produce results in the field of B physics. We currently have $\approx 220 \text{ pb}^{-1}$ of data on

tape, and expect to get up to $\approx 500 \text{ pb}^{-1}$ by the end of 2004.

As a stepping stone to B_s mixing, we plan to measure ΔM_d to benchmark our analyses techniques. In addition, we are pursuing a vigorous program, which includes measurement of B lifetimes, rare decays, studies of quarkonia, beauty baryons, B_c , etc.

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REFERENCES

1. M. Battaglia, *etal.*, The CKM matrix and the unitarity triangle, Tech. rep., arXiv:hep-ph/0304132 (2003).
2. K. Hagiwara, *etal.*, *Physical Review D*, **66**, 1 (2002).

³ An excellent review, covering both theory and experiment, can be found at <http://hep.physics.indiana.edu/~zieminsk/talks.html>. Select the Trento workshop talk